# LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

Published by

The Texas Company, 135 East 42nd Street, New York City

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Vol. XXIV November, 1938 No. 11

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# Quick-Freezing and Food Preservation

IN March of last year, Clarence Francis discussed the history of food preservation before Princeton University as a member of the Guild of Brackett Lectures. Mr. Francis' was a fascinating duty, his research was intensive and his presentation most instructive; he thoroughly convinced his audience of the relation of food preservation to their daily comfort and well being.

It is our privilege to go a step further than Mr. Francis in discussing the means whereby the objective is attained and the materials required. Obviously, the Petroleum Industry becomes a partner, for the necessary mechanisms can be made to function dependably only by positive lubrication of their working elements.

Food preservation is a function of refrigeration and cold storage. There was a time when "old-wives" tales warned against this latter; it was believed that it did something to the products being stored. Probably so, in those early days of an industry, where control of temperatures was relatively inaccurate; where transportation methods were so slow as to permit of preliminary fermentation before the products even went into storage; and where the average length of time from source to market was so much longer than it is today.

But research and the chemist have freed us of those worries. We have learned of the cell structure of all foods subjected to quick-freezing; we know of their relative rates of evaporation and oxidation; and our knowledge of ferments and enzymes is extensive. So by planning our freezing and storage procedure as the chemist dictates, and utilizing the methods of developing cold which the engineer has perfected, we can eat our oysters in August and strawberries in January with complete assurance that they could be no better than were we to take them straight from the beds at the height of their respective seasons.

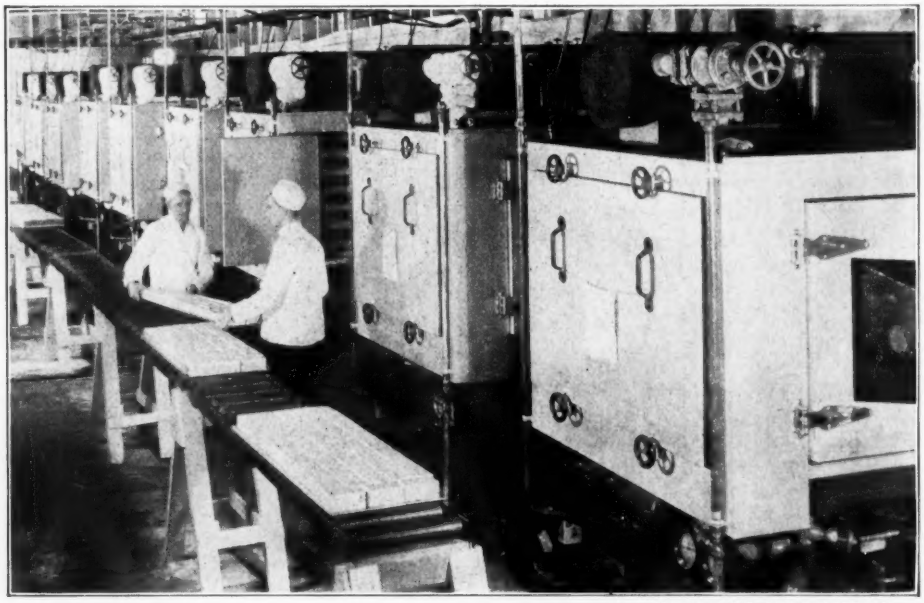
The process involved is unique in that it has required microscopic study of cell contents and the rate of crystallization. All foodstuffs contain moisture. The basis of satisfactory preservation is the congealing of this moisture to crystalline form to retard dehydration and fermentation. When relatively large crystals are formed in the cell structure, the latter may be ruptured, in which case, defrosting will disturb the natural texture of the product to affect the flavor.

The slower the freezing process the larger the crystals. This fact formed the basis upon which research covering quick-freezing was founded, coupled with the fact that heat-transfer by conduction is more rapid than by convection. So our modern quick-freezing processes are based upon contact chilling rather than gaseous or liquid cooling.

Quick-Freezing is definitely allied to the Ice Industry. By their mutual expansion they have demonstrated the versatility of ice as a medium for food preservation, and the ammonia compressor for freezing purposes. Through the perfection of the several methods

of quick-freezing, we have in turn reverted to a dependence upon the ice machine for locker preservation of our perishable foodstuffs.

Ice is manufactured by mechanical refrigeration—mechanical in the sense that the compressor is a mechanism which involves the



*Courtesy of Frosted Foods Sales Corp.*

Fig. 1—A battery of Birdseye quick-freezing units. These are all portable and therefore lend themselves to transportation wherever packing is to be done. At the same time, a relatively permanent set-up can be established if desired with a minimum of piping and auxiliaries.

principles of mechanics in its operation. These same principles of mechanics apply to quick-freezing, with the same basic refrigerants.

## How Low Temperatures Affect Lubrication

The lubricating engineer becomes interested in this quick-freezing process by reason of the low temperatures which must be developed to attain the desired degree of freezing within the time specified for the food products under treatment. This may require minimums as low as 45 to 50 degrees below zero Fahrenheit. In cooperation with the petroleum chemist, he must provide oils for compressor lubrication which will give dependable protection and resist carry-over with the refrigerant to the heat-exchange parts of the system. As this heat exchange subjects any oil present to quite as low temperatures as are brought about by expansion and evaporation of the refrigerant, the oil must contain no component which will congeal in sufficient volume to remain on the expansion valve or within the evaporator. This will cause faulty operation of the valve and reduce the subsequent rate of heat transfer in the evaporator.

The extent to which oil carry-over will occur depends in some part upon the refrigerant under pressure. Ammonia is capable of a more or less physical mixture with hydrocarbon lubricating oils. Other refrigerants, also, require very careful consideration from this point of view—notably the fluorinated and chlorinated "Freons," Carrene and Methyl chloride. These refrigerants, however, tend to reduce the viscosity of the oils with which they go into solution. Oil-refrigerant mixtures are hard to break even with the most efficient oil separators available; hence the usual precautions to keep the components apart wherever possible.

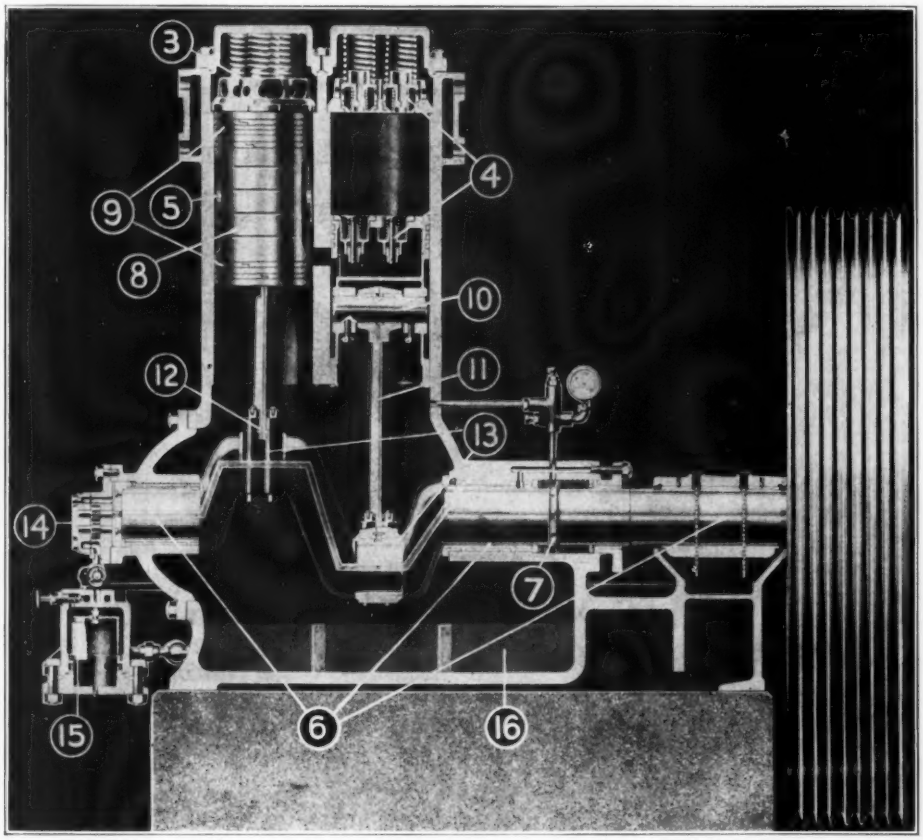
In quick-freezing refrigeration, we are chiefly concerned with ammonia. With this chemical, oil trap or separator installations can be more practicably designed, for the oil is present in the high-side in the liquid phase, although it may be in very finely dispersed form. Liquids can be more effectively separated or precipitated from gases than from liquids.

## METHODS AND MATERIALS

The installation required has been designed to embody the principles of portability. Vegetables, fish and certain meat products are seasonal; they do not conserve their flavor if allowed to age, hence they must be quick-frozen as soon as possible after harvesting or dressing. Fish, peas, shell food and strawberries are especially perishable. So the freezer

must be brought to the source rather than the product to the freezer.

This feature of portability is a definite advantage to the packer. Normally in setting up such a plant, he is only concerned with power and water supply. It may prove a headache to the lubricating engineer, however, due to cooling water temperature conditions as discussed elsewhere. Furthermore, he must provide for wide (and perhaps temporary) distribution of his specialty refrigerating oils for compressor lubrication. Both fortunately are quite practicable.




*Courtesy of Baker Ice Machine Co., Inc.*

Fig. 2—Cutaway of a Baker ammonia compressor as employed in the frosted food industry. The very low temperatures of operation require careful attention to lubrication and the use of specially refined quality oils. The above is of interest as it shows the details of the oiling system. 3, shows the removable safety heads and valves; 4, the discharge and suction valves; 5, the honed cylinders; 6, the three-bearing crankshaft; 7, the shaft packing; 8, the double trunk-type pistons; 9, the piston rings; 10, the piston pins and bushings; 11, and 12, the connecting rods; 13, the oversize bearings; 14, the oil pump; and 15 and 16, the oil filters and reservoirs.

## Compressor Design

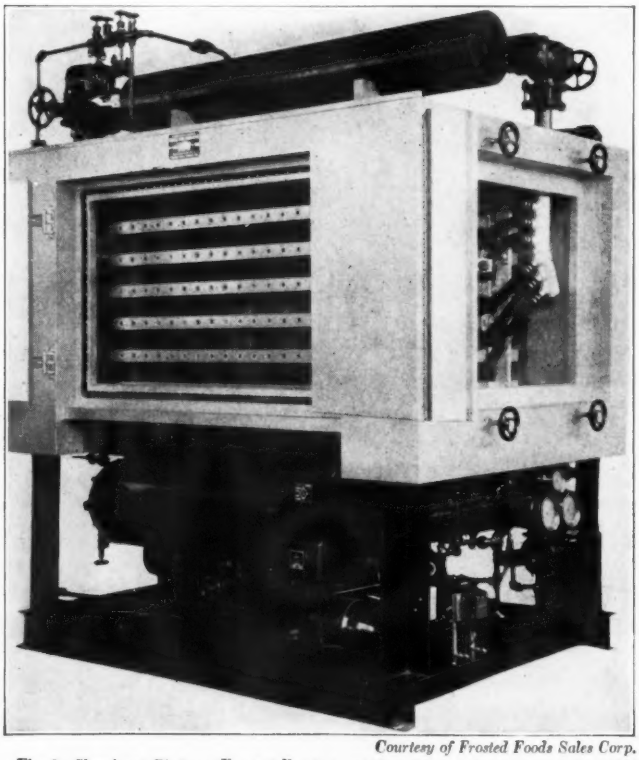
The vertical, reciprocating, enclosed trunk-type refrigerating compressor so familiar in the manufacture of ice is quite generally used for quick-freezing and for maintenance of the required cold conditions in locker storage. In other words, refrigeration by compression is practiced. For the benefit of the layman, such a system includes a compressor, oil separator, condenser, receiver, expansion valve, and an evaporator or refrigerator.

In the compression process the refrigerant or cooling agent is recovered after each expansion by means of mechanical compression. With certain variations in construction and arrangement of equipment, the compression process is adaptable to any one of the modern accepted refrigerants.

In service, the gaseous refrigerant must be sufficiently compressed and cooled to convert it to liquid form. Under compression alone, it will still remain as a gas due to the fact that the application of pressure raises the temperature above the liquefaction point. So some form of condenser is necessary.

Prior to condensation, however, the gas is usually passed through a suitable oil separator or trap in an attempt to free it of any excess

lubricant that may have passed over from the compressor cylinders. From the oil separator the hot refrigerant then passes to the cooling coils of the condenser, where its temperature is sufficiently lowered by means of air or cold circulating water to convert it to liquid form. It is then capable of cooling.



*Courtesy of Frosted Foods Sales Corp.*

Fig. 3—Showing a Birdseye Frosted Foods portable quick-freezing unit complete with compressor. This is a cabinet type froster containing five compartments and five trays. The Birdseye process consists of freezing packaged products under controlled pressure between refrigerated flat metal surfaces such as belts or plates.

On the frame base, under the cabinet is located the compressor; motor, condenser, hydraulic lift cylinder, hydraulic oil tank and pressure pump direct connected to a $\frac{1}{2}$ H.P. motor.

This latter is brought about by passing the refrigerant through an expansion or regulating valve to the evaporating side of the system. Here, by virtue of a considerable drop in pressure, it evaporates and takes up heat, returning thereafter to the gaseous state. In so doing, it cools down to a relatively low temperature, and as a result, absorbs heat from the material to be cooled or frozen. The refrigerant is then returned to the compressor for repetition of the cycle.

## How Quick Freezing Temperatures Affect Oil Selection

By reason of the unusually low temperatures required in quick-freezing operations the compressor oil should be capable of meeting these without congealing or ice formation at the expansion valve, and without deposition in the evaporator. This requires an oil which is virtually free from water and one which shows a sufficiently low pour test to assure of only the necessary amount of paraffinic hydrocarbons to give balanced lubricating ability. The viscosity should normally range from 150 to 300 seconds Saybolt Universal, according to compressor design and the operating conditions.

The other physical characteristics are of little concern to the operator; they have no bearing upon the lubricating ability of a refrigerating compressor oil and may only be indicative of the type of crude from which the oil has been produced. We might, however, except the flash point, which may require consideration in quick-freezing service where single-stage or booster compressors without intercoolers are employed under which conditions the compression temperature may approach 250 degrees Fahrenheit on the discharge side. Even this, however, should not cause any concern in normal service for the flash point of the average high-quality compressor oil will be about one hundred degrees higher. As ordinarily understood, the flash point is a rough measure of evaporation.

## The Liquid Inter-Cooler

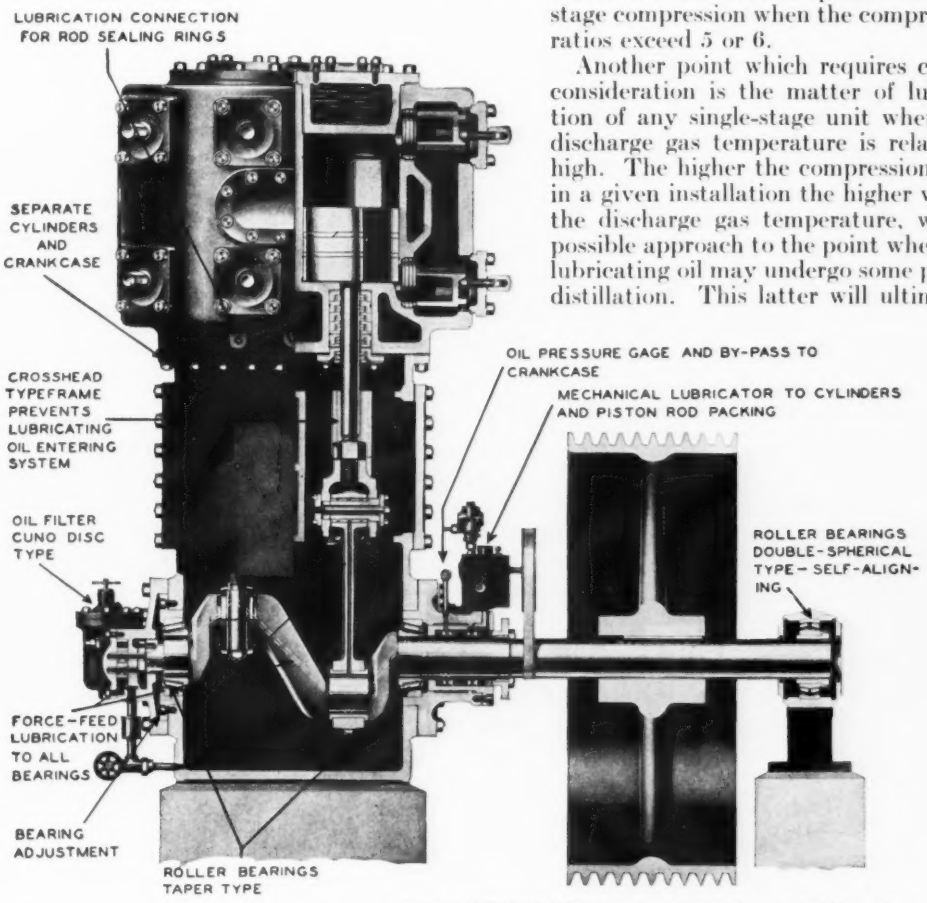
The use of a liquid inter-cooler between compressor stages is very beneficial on a two-stage machine, or where a booster compressor is used in connection with an existing refrigerating machine. This liquid inter-cooler desuperheats the discharge gas of the booster or the low pressure stage, thus allowing the succeeding compressor cylinder to operate at greater efficiency and maintain a lower final discharge gas temperature than would otherwise be possible.

Some refrigeration installations use single stage compressors over a wide range of compression ratios, with the inevitable high temperature discharge gas due to such design. If, in order to obtain low temperature evaporator conditions, a booster compressor is added to this system without the use of a desuperheater or inter-cooler, the temperature of the final discharge gas may be so high as to cause carbonization of the lubricating oil. A parallel of this may be seen in air compressor service where inter-coolers are used to prevent excessive discharge gas temperatures.

## Potential Extremes in Temperature

In any refrigerating system care must be taken to obtain a proper economic balance between the initial cost of the equipment and the prevailing operating costs. Any reciprocating compressor is limited in its capacity by the compression ratios. No fixed rule may be laid down as to the most economical compression ratio since each problem involves its own peculiar variations such as percent clearances of the compressor, its general design, and the operating conditions. It is sufficient to say, however, that attention should be paid to multiple stage compression when the compression ratios exceed 5 or 6.

Another point which requires careful consideration is the matter of lubrication of any single-stage unit where the discharge gas temperature is relatively high. The higher the compression ratio in a given installation the higher will be the discharge gas temperature, with a possible approach to the point where the lubricating oil may undergo some partial distillation. This latter will ultimately result in carbon residue accumulations and increase in the normal viscosity of the lubricating oil. All these objections may be more or less overcome by using a properly designed booster or multiple-stage compression system together with a suitably refined oil. This design will subject any lubricating oil carried over by the discharge on the high side to lower temperatures than experienced in normal single stage refrigeration service.


LUBRICATION CONNECTION FOR ROD SEALING RINGS
SEPARATE CYLINDERS AND CRANKCASE
CROSSHEAD TYPEFRAME PREVENTS LUBRICATING OIL ENTERING SYSTEM
OIL FILTER CUNO DISC TYPE
FORCE-FEED LUBRICATION TO ALL BEARINGS
BEARING ADJUSTMENT
ROLLER BEARINGS TAPER TYPE
OIL PRESSURE GAGE AND BY-PASS TO CRANKCASE
MECHANICAL LUBRICATOR TO CYLINDERS AND PISTON ROD PACKING
ROLLER BEARINGS DOUBLE-SPHERICAL TYPE-SELF-ALIGNING

*Courtesy of Carbondale Division—Worthington Pump & Machinery Corp.*

Fig. 4—Lubrication details of the Worthington-Carbondale vertical, duplex, double-acting enclosed crankcase refrigeration compressor. By pressure lubricating the bearings and cylinders independently, control of oil flow to the latter can be positively maintained. With the added precaution of filtering the crankcase oil, protection against contamination is attained.

volumetric efficiency of the machine and its relation to the ratios of compression through which the compressor operates, i.e., the greater the ratios of compression the lower the volumetric efficiency. It can, therefore, be seen that a point can be reached in the scale of compression ratios at which the compressor will have no capacity whatsoever, due to the re-expansion of the gas filling the clearance volumes. The engineer therefore seeks to overcome this problem by the use of multiple stage compressors wherein two or more compressor cylinders are used in series; each compressor cylinder compressing the gas to a pre-determined range of

A booster compressor added to any existing refrigerating system merely creates a multiple-stage system, permitting the attainment of lower temperatures in any connected evapora-

tor. A booster may be applied to a single stage machine, as well as to a two or more stage machine with equal success, if practicable engineering and economic principles are appreciated.

The booster compressor system is no more complicated than any other refrigerating cycle. It is only important to recognize the higher discharge gas temperatures and the necessity for their proper desuperheating before introduction to succeeding stages. The booster compressor may be of the reciprocating, rotary or centrifugal type compatible with engineering design and the lubricating problems. The latter differ but little as compared with those of the same machines when used in the ice industry.

## Significance of the Pour Test

How a petroleum oil will behave when it is subjected to low temperature conditions has led to considerable study of the methods of test to enable accurate determination of the temperature at which congealing begins and fluidity is retarded. This knowledge is obviously of advantage to the chemist who is concerned with the manufacture of refrigerating oils, and to the operator who must put them into application. The American Society for Testing Materials has established standard methods of test in this regard, and noted certain significant factors which may affect the test.*

The physical effect of temperature is an interesting phenomenon when considered with respect to various fluids. In the case of petroleum oils it is not the same as with the more simple fluids such as water, alcohol or glycerine. These all have fixed and accurately ascertainable freezing points at which a complete change from the liquid to the solid phase takes place. Petroleum oils, being complex combinations of hydrocarbons of various melting or freezing points, behave like solutions and frequently certain of these constituents will congeal as the temperature is lowered, before solidification of the entire mixture.

These are interesting phenomena which can only be explained by change in the inner or molecular structure. They are the reasons why such infinite care must be taken in observing the pour test of an oil under standardized conditions, and why the obtaining of check results by different laboratories is so often difficult. But a slight variation in the rate of cooling or the least agitation or stirring may affect the results materially. Even the preheating of a sample, by carrying it in a closed car on a hot summer day may throw the subsequent laboratory results off to some extent. In other words, the pour test is only of comparative value due to the methods of test being designed to cover a variety of variables.

It is especially important for the laboratory to avoid stirring or agitation while cooling as movement of the oil destroys or changes the

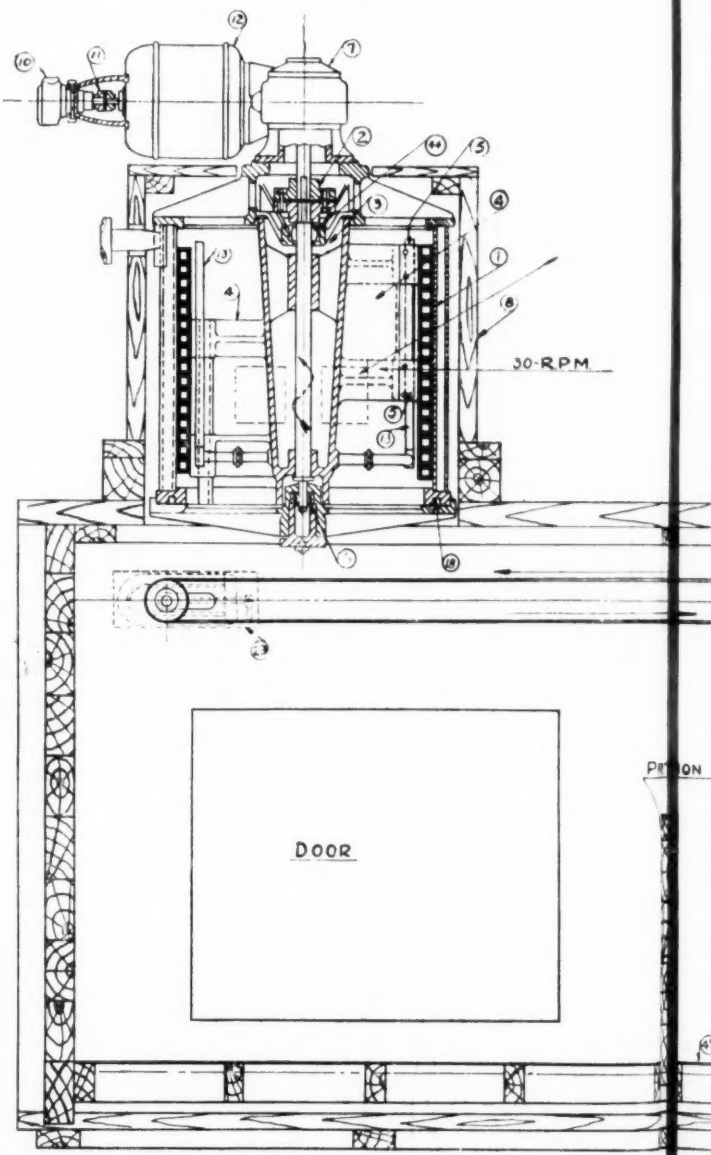
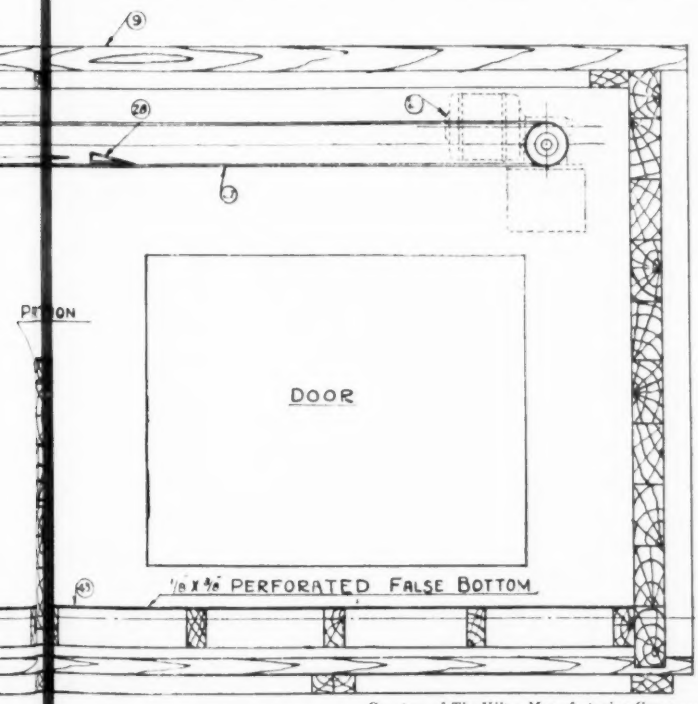



Fig. 5—Details of the Vilter "Pak-Ice" machine. In addition to lubrication of the refri[illegible] elec[illegible] cated chain and gear mechanisms. Unit lubrication is provided for with complete covera[illegible] worl[illegible]

* The Significance of Tests of Petroleum Products. A report prepared by Committee D-2, American Society for Testing Materials, 1937.

fine network of microscopic particles of paraffinic bodies which are separating out. Authorities feel that an oil which is stirred will solidify at lower temperature and hence show a false pour test.

The American Society for Testing Materials offers an interesting significance to the pour test from an operating viewpoint, viz.: "The pour point gives an indication of the temperature below which it may not be possible to pour or remove an oil from its container, or below which it might be dangerous to use the oil in gravity lubricating systems, where the head tending to produce flow is small. However, it should be borne in mind that the size and shape of the container, the head or force exerted upon the oil, and the nature of its physical structure when solidified, all have an effect upon its tendency to flow. Accordingly, it is self-evident that no single test can be devised which can be taken as a positive and direct measure of the performance of an oil under all conditions of service, and the pour test should be regarded as giving only an indication of what may be expected."




*Courtesy of The Vilter Manufacturing Company*

...e refrig... element, one must consider the grease lubricated sleeve and roller bearings, and oil lubri... overan... working parts to protect the lubricants.

## Viscosity a Function of Operating Conditions

Lubrication of the ammonia compressor as designed for ice making, quick freezing or cold storage service, requires consideration of the oil viscosity from a constructional and operating viewpoint. The oil is not subject to appreciable viscosity-reduction when mixed with the refrigerant, as occurs with the chlorinated or fluorinated types of refrigerants; so we are not concerned with the film strength.

Oil film formation and maintenance on cylinder walls and bearings, however, are of vital importance; the viscosity has a direct relation thereto. It is a definite factor where enclosed crankcase, high-speed machines are used in connection with evaporating systems which may allow liquid refrigerant to return to the compressor. As a rule, oils should be used which will stand considerable churning in the presence of the refrigerant and a certain amount of water.

The one oil often lubricates the entire machine. As a result, it must be capable of serving both the cylinders and the bearings. It should not emulsify to any great extent, for this might result in clogging of the lubricating system or impairment of refrigeration should it work past the piston rings and over to the refrigerating side.

The physical condition of the valves, piston rings and stuffing boxes must also be considered in deciding upon the viscosity of oil to use. Practically as important as its lubricating properties will be the seal and compression-forming ability. If the cylinder walls and moving parts are in first-class condition, a straight mineral oil of from 150 to 200 seconds Saybolt viscosity at 100 degrees Fahr., should give adequate lubrication.

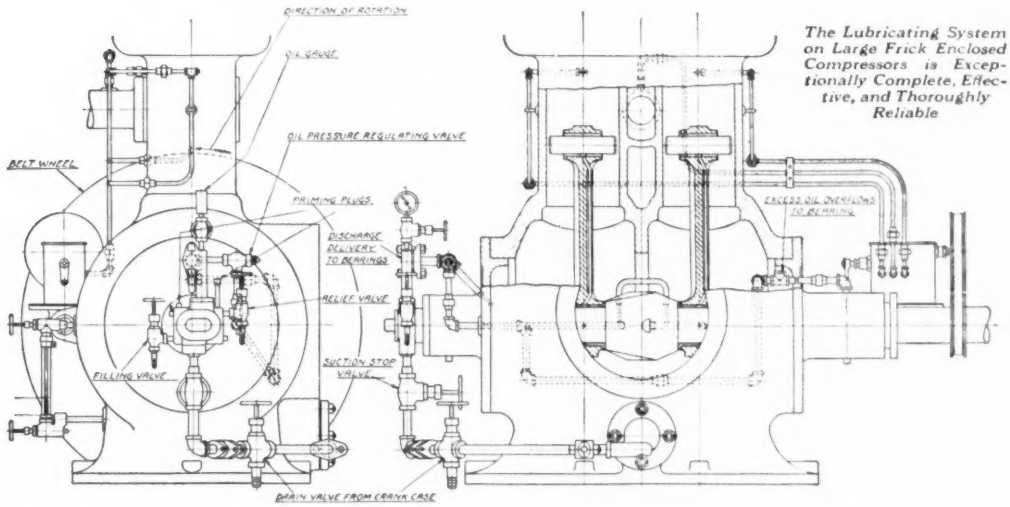
On the other hand, in large machines, or those where the cylinder walls are scored or rings are worn, an oil of higher viscosity may be essential to maintain the requisite seal and degree of compression. Under such conditions an oil having a viscosity around 300 seconds Saybolt at 100 degrees Fahr., should be satisfactory.

## Valve Design

Changes in compressor design over recent years have lead to conditions involving a variety of lubrication problems which were not prevalent theretofore. In this regard, valve design must be carefully considered, viz., when we dealt with compressors equipped with poppet valves, clearance spaces were held to a minimum. The use of plate valves today, however, requires the separation of the plates with grid work; it is this latter which necessarily imposes an added clearance volume in the head of the machine or at the top of the piston.

In operation, with the older type poppet valve machine (especially in vertical location), if the expansion valve was slightly overfed and liquid ammonia reached the machine there might be a great deal of slamming of the head, this will bring about pre-cooling and serve as an auxiliary evaporator of any entrapped liquid.

An opposite condition prevails, however, where a flooded system is so arranged that the




*The Lubricating System on Large Frick Enclosed Compressors is Exceptionally Complete, Effective, and Thoroughly Reliable*

*Courtesy of Frick Company*

Fig. 6—These details of the base of a Frick compressor are especially interesting as they indicate the features of the lubricating system, the piping and the course followed by the oil. The latter is in constant circulation, and make-up can be charged without stopping the machine.

which would make sufficient noise to alarm the attendant and cause him to cut back on the expansion valve. With the grid type valve, however, a large quantity of refrigerant can pass through the machine without any appreciable knocking or noise, and the condition can proceed without even attracting the attention of the attendant. The net result of large quantities of liquid refrigerant passing through the compressor is the lowering of the temperature of the cylinder walls to a point below which condensation takes place upon the slightest compression.

With refrigerants such as ammonia, condensation on the wall of a vertical cylinder washes the lubricant from the cold side and scoring of the surface or wear of the piston rings results. This condition does not apply as actively to a horizontal machine for the reason that the refrigerant in nearly every case enters at the same end at which it is discharged and therefore, the cold fluid is more or less immediately mixed with the remaining hot gas in the compressor. The obvious remedy for such a condition is to locate some form of suction trap in the suction line which will lower the velocity of the incoming gas and cause it to trap out the liquid. Such a trap should be provided with a small coil through which the refrigerant may be passed on its way to the evaporator from the receiver or condenser; gas velocities are very low. In this case the gases arrive at the machine comparatively highly saturated. This, in turn, results in a lower discharge temperature, and if the lubricant is not of sufficient lubricating ability under such conditions, it may not be able to protect adequately the cylinder walls and rings against abnormal wear. When the amount of superheat in the suction gas is sufficiently great to cause extremely high discharge temperatures (as might occur where the ratios of compression are very great), a desuperheater can be located adjacent to the machine to reduce the temperature of the incoming gas to a point nearer to saturation, and two-stage compression can be adopted if required by conditions.

## Effect of Cooling Water Temperature

Quick freezing may require exacting duty from the oil used for compressor lubrication, according to the temperature of the cooling water. The latter will have a definite effect upon the discharge temperature and hence the amount of heat to which the lubricating oil will be exposed on the cylinder walls and during the course of carry-over by the refrigerant. It is important to consider this detail when selecting the oil, whenever one is dealing with the popular type of portable quick freezing unit. In this consideration, we must remember that the process is applicable from the Gulf Coast to

Canada. Obviously, water conditions will, therefore, vary widely, for the well water of Maine will be much cooler than the normal river or stream water of Florida; and in between these ranges there may be almost as much variation according to the source or amounts of water available. For most effective compressor lubrication, an inlet cooling water temperature approximating 50 to 60 degrees Fahr., is very desirable. This will enable adequate heat transfer and yet, not too high an outlet temperature. The latter is desirable where cooling towers or heat exchangers must be employed to enable re-usage of the water supply.

So the compressor oil may have to meet almost automotive conditions on the high side, and yet possess ample fluidity at temperatures as low as minus 50 degrees Fahr., to insure against congealing in the evaporator or at the expansion valve.

## The Oil Characteristics

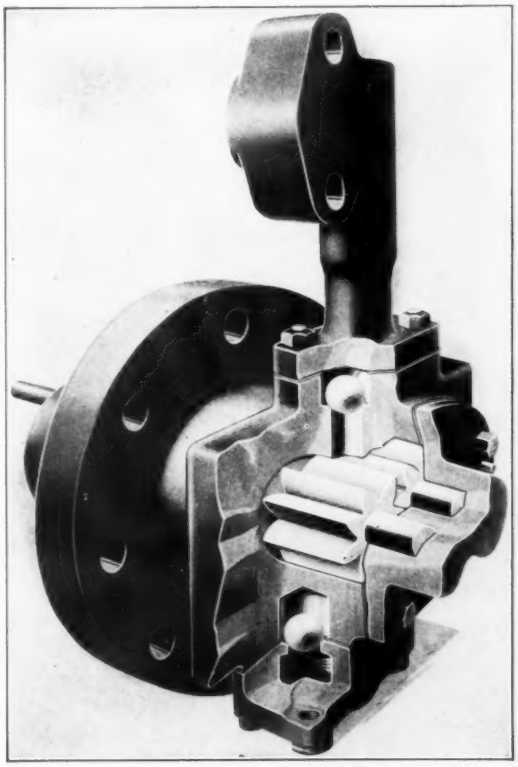
The Petroleum Industry uses the utmost care in selecting their crude oil stocks to attain the latter objective. Resistance to breakdown under high temperature conditions in turn is assured by the use of selective solvents for removing the unstable hydrocarbon components during the course of refining. The result has been the development of a series of processes capable of producing a type of refrigerating oil today so superior to the product the oil industry could offer but a decade ago, that there is no comparison.

This superiority is evidenced to the refrigerating plant operator by more dependable performance, resistance to gum formation and the normal absence of an excess of objectionable deposits.

The chemist denotes this superiority by comparing physical specifications, and the use of certain accelerated breakdown tests. These latter are based upon resistance to oxidation and normally subject the oil to controlled and elevated pressure and temperature conditions in an atmosphere of oxygen. If such an oil will resist the precipitation of sludge or gummy matter under such conditions, practical experience has indicated it will function satisfactorily in the presence of any of the refrigerants generally used today. In other words, the oil will meet the requirements of the refrigeration industry. The operator must respect these facts when selecting his compressor oil. Then he must go a step further and look into his operating conditions, with full appreciation that lubrication of the refrigerating compressor is unique in that the effect of petroleum oils upon parts not requiring lubrication is quite as important as the lubricating ability. In other words, he must look beyond the compressor and consider what may happen if his oil becomes so sluggish, when carried over by the refrigerant to the expansion coils, as to congeal therein and reduce the rate of heat transfer and the refrigerating capacity. This requires knowledge not only of the pour test of the oil he may be considering, but also the minimum temperatures which may prevail in the evaporator.

When refrigerating oils are subjected to extremely low temperature conditions, wax deposits may be developed. This is a natural phenomenon with any petroleum lubricant, although some can withstand lower temperatures better than others.

It is advisable to be aware of this possibility when handling any refrigeration system and to be informed of the most practicable method of preventing wax deposits from becoming detrimental. There will be some refrigerating engineers who will contend that it is the duty of the petroleum industry to so refine their refrigerating oils as to preclude this possibility. Such a procedure is quite practicable, but costly and not at all essential.



*Courtesy of Frick Company*

Fig. 7—Sectional view of the Frick force feed oil pump showing gear assembly and ball checks. This pump draws oil from the bottom of the crankcase through a screen, passing it thence to the bearings under pressure of from 15 to 25 pounds above the suction pressure of the ammonia.

It is far better to consider mechanical means

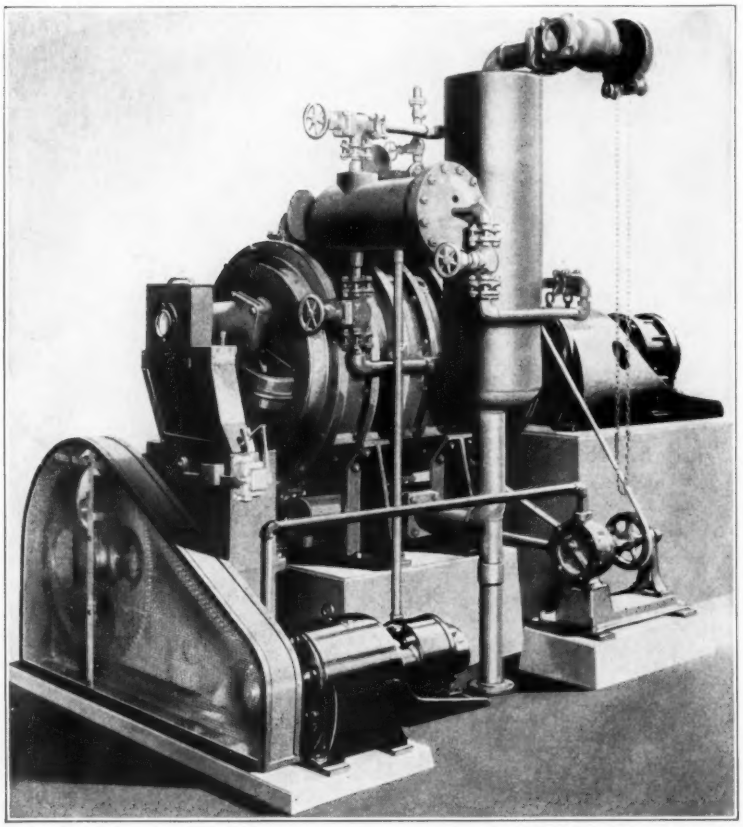
of preventing the oil from reaching the evaporator where its wax content might be most harmful.

### How the Oil Separator Serves the Purpose

The oil separator is a most effective medium in this regard. This unit should serve to remove any particles of oil from the refrigerant while it is in the gaseous form, after it has left the compressor. The larger the oil particles, and the lower the velocity, the more effective will be the separator. It should, therefore, be located at a sufficient distance away from the compressor to permit of adequate precipitation of the oil. The capacity should be ample so that the velocity of the gas passing through (as already stated) will not be too high; furthermore, it should be capable of taking an overload, should an excessive amount of oil be fed to the compressor.

The oil separator functions at its best when it is placed between the discharge of the compressor and the point of entry of the gas into the condenser. In certain machines, a drain valve also may be installed below the condenser to enable removal of any oil that may have passed the separator. It should never be set too near the compressor, otherwise the rush of hot gas will prevent proper condensation and collection of the oil.

Oil vaporization is always a possibility due to the heat of compression which prevails. The resultant vapor will tend to pass into the system with the refrigerant, to condense and remain in the colder parts, unless it is removed before it enters the condenser. In consequence, the separator should be located as close to the condenser and as far away from the compressor as possible. It should also be of sufficient size to allow of ample reduction in the velocity of the gas to permit of effective separation. A smaller separator located some distance from the compressor may often prove more effective than a large separator located nearby.



*Courtesy of The Vilter Manufacturing Co.*

Fig. 8—The Vilter booster compressor unit as designed to apply ammonia to quick-freezing operations. The function of this type of mechanism and its lubrication has been discussed in the accompanying text.

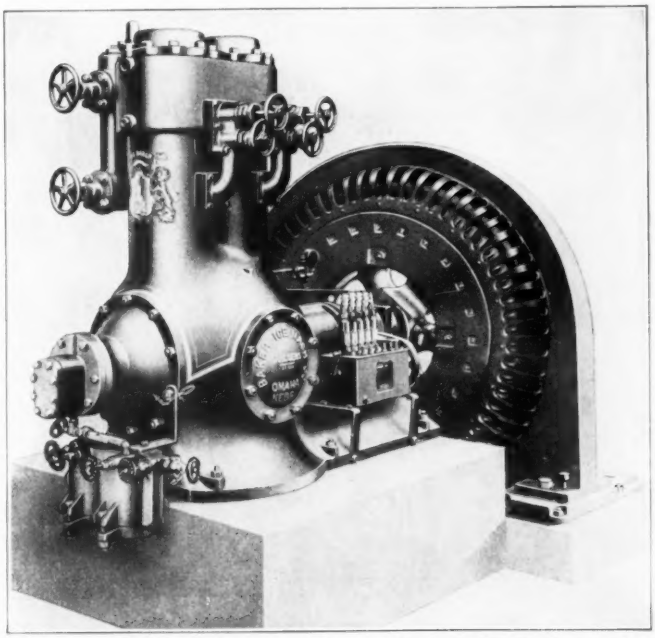
Where the main oil separator can only be set adjacent to the compressor, it is well to use an oil of as low an atomizing tendency as possible. This property will usually accompany high viscosity. The choice of a heavier oil would, therefore, solve the problem to some extent. In general, an oil of a viscosity of from 200 to 300 seconds Saybolt at 100 degrees Fahr., will be suitable.

The efficiency of an oil separator can be checked by comparing the amount of oil removed from it with the amount fed to the compressor. Any extensive difference would indicate that the oil is not being entirely removed or trapped. Allowance, of course, should be made for oil leakage around the stuffing box, although to just what extent this may occur will depend on the individual installation, the care given to lubrication, and the original viscosity of the compressor oil. Water cooling has proved advantageous in improving separator efficiency.

### Methods of Lubrication

Of necessity the design of the lubricating

system on the type of compressor employed in quick-freezing or cold storage food preservation service will depend upon the size of the installation. Very often it is self-contained, although the mechanical force feed lubricator is quite as applicable as a built-in pressure system, especially where the plant is permanent. In addition, we have another alternate in splash lubrication—also a type of built-in method of oil distribution. Splash lubrication is best adapted to the vertical compressor; force feed, however, can be applied to either the vertical or horizontal machine. Regardless of the actual means of oil circulation, however, it is obvious that the system involved for the lubrication of compressor cylinders stuffing boxes and enclosed bearings will have a decided influence upon the grade of the oil that should be used.



*Courtesy of Baker Ice Machine Company, Inc.*

Fig. 9—The type of Baker large capacity ammonia compressor as used in connection with frozen food plants. This unit takes the gas from a booster compressor (at low pressure) and recompresses it for condensing purposes.

*Splash Circulation*

Oil is distributed by splash at each revolution of the crank, the level in the crankcase being maintained just high enough to permit the crank to dip and splash the necessary amount of oil to the cylinder walls. Continued operation will result in the crankcase being filled with a lubricating vapor above the main body of oil which will insure adequate lubrication of main, wrist pin and crank pin bearings.

The oil level must never be too high. This requires careful attention especially when recharging the case with oil. If too much oil is used, churning by the crank will cause violent agitation in the main body of oil to oftentimes preclude effective precipitation of any solid impurities that may have gained entry. There would also be possibility of loss of lubricant past the piston rings, with subsequent entry of an excess of oil into the condensing and evaporating parts of the system. The rate of heat transfer might thereby be affected. This will be apt to occur more actively wherever the rings may be loose. Here, if the crankcase contains too much oil or agitation is too violent, the excess which naturally will reach the cylinder walls will tend to work past the rings, just as so frequently occurs in an automobile engine. This is often termed oil pumping; it is not only wasteful, but also a detriment, for oil in the refrigerating lines will impose an added load on the oil separator. Furthermore, if by chance the oil is not of sufficiently low pour test there will be possibility of its congealment within the system, with reduction in the amount of refrigeration developed as already intimated. Even with rings in good condition oil pumping may develop if liquid refrigerant is carried over to the cylinders from the evaporator.

Use of excess oil in a splash lubricated system will also involve the possibility of difficulty when draining and cleaning, especially where sludging has taken place. Continued churning of improperly refined oils will cause sludge formation. In part, this is due to oxidation; it will be most probable where water is present or the oil is laden with very much foreign matter, such as dirt, metallic particles, or carbon. Regular periods for cleaning must therefore be established with study of the condition of the used oil, for this will very often indicate both the approximate suitability of the latter and the extent to which effective lubrication is practicable.

*Pressure Systems*

Where larger types of vertical or horizontal refrigerating machines are involved, pressure lubrication is used with marked success. Pressure assures of quite accurate control of the amount of oil delivered to cylinder walls and compressor bearings. There is another advantage also; i.e., the possibility of effective

filtration or purification of the oil where there is provision for circulation.

*Mechanical Force Feed Lubricators*

External lubricators of this type are extensively used where compressor cylinders only are to be pressure oiled. Excellent economy will be attained by regulating such lubricators so that just enough oil is delivered to maintain the requisite lubricating films, with the least amount of excess.

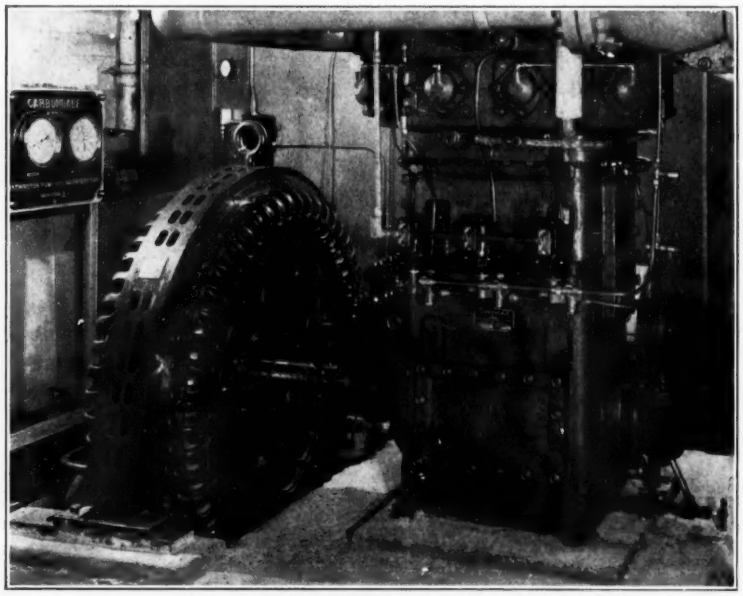
On many types of machines, it is good practice to lubricate internal and external parts individually. In other words, using the mechanical lubricator with perhaps three outlets for cylinder and stuffing box service, and an independent gravity or mechanical pressure circulating system for all external bearings.

Mechanical force feed lubricators are especially adapted to cylinder and rod lubrication via the oil lantern, or oil recess within the piston rod stuffing box. By properly constructing a stuffing box with a lead to come from the lubricator, it is possible to operate the piston rod continually through a ring of oil. In this way, effective rod lubrication, as well as sealing against pressure, are maintained.

To lubricate the cylinders in addition, in some designs it is only necessary to deliver a certain excess of oil to the stuffing box lantern and provide a so-called overflow pipe to carry this to the refrigerant suction line adjacent to the cylinder. In effect, this is similar to the principles of steam cylinder lubrication, the refrigerating gas being impregnated with vaporized lubricant prior to its passage through the compressor.

Hand pump oilers can also be used for this purpose, but mechanical force feed lubricators are more positive and require less attention on the part of the operator.

Vertical compressors of the enclosed crankcase type are most suitable for automatic controlled systems, which are usually of comparatively small capacity, also systems where very little attendance is available. In the vertical machine the side thrust is taken directly by the cylinder wall which tends to make the cylinder wear to oval shape. This thrust varies at different points of the stroke so that the wear on the cylinder wall is not even over the entire stroke.



*Courtesy of Carbondale Division—Worthington Pump & Machinery Corporation*

Fig. 10—Showing a Carbondale Vertical, duplex, double-acting compressor in food market refrigeration service. This unit is also adapted to service as a low pressure ammonia booster compressor.

Horizontal compressors on the other hand have connecting rods two or three feet longer than vertical machines, and the component of thrust at right angles to the travel of the piston is far less in a horizontal machine. This thrust is taken up by the crosshead guides which are readily accessible for adjustment. The only wear in the cylinder therefore is caused by that part of the piston weight which is unbalanced by the pressure of the guide and long stuffing box.



Printed in U. S. A. by
EDGAR C. RUWE CO., INC.
72 Washington St., N. Y. C.